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A SYNTHESIS OF THE ELEMENTS OF RANDOM-SHIP SYNOPTIC REPORTS TO DERIVE CLIMATOLOGICAL MARINE-FOG FREQUENCIES

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THESIS

A Synthesis of the Elements of
Random-Ship Synoptic Reports to Derive
Climatological Marine-Fog Frequencies

by

Ronald Earl Englebretson

September 1974

Thesis Advisor: R. J. Renard

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by

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Lieutenant, United States Navy

Submitted in partial fulfillment of the requirements for the degree of

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I. INTRODUCTION

A. BACKGROUND

The occurrence of marine fog is a problem to all ships at sea. Commercial ships are faced with the danger of collision as well as delay in enroute time due to reduced speeds in low visibility. Navy units, in addition to collision, must be concerned with reduced visibility effects on aircraft launch and recovery operations and multi-ship training maneuvers. Wheeler [1] addresses the costs in dollars and lives, as related to low-visibility operations, incurred by the United States Navy during the period of 1969 through early 1974. Aircraft related losses alone totaled 63 million dollars and 29 lives.

Department of Defense interest in marine fog has been recently evidenced by Annual Conferences on Marine Fog, sponsored by the Naval Air Systems Command, the second of which was held at the Naval Postgraduate School (NPS), Monterey, California on 8-9 January 1974. The agenda are generally directed toward understanding the physics of marine fog with the ultimate goal of forecasting same.

While attempts to numerically model the behavior of these fogs are proceeding at the United States Navy's Environmental Prediction Research Facility (EPRF), Monterey, California [2], and elsewhere, the NPS group is concentrating on the analysis and forecasting of marine fog.

Presuming the need for a valid climatology of marine fog statistics in any synoptic-scale forecast approach, a number of existing climatologies of fog frequency for the North Pacific Ocean area were reviewed [3], [4], [5], [6], [7], [8]. Collectively, these indicate contradictory fog frequencies and frequency gradients. Additionally, single station or regional climatologies such as [5], [6], [7], [8] are of limited usefulness when working with a hemispheric forecast model.

In particular, questions of validity arise when intercomparisons are made for specific regions. As an example, references [3] and [6] may be compared. Reference [3], published by the National Oceanic and Atmospheric Administration's National Climatic Center, Asheville, North Carolina for the Commander, Naval Weather Service Command, presents, among other charts, a worldwide summary of frequencies of fog. Reference [6] is a regional fog climatology prepared at Fleet Weather Central, Alameda, California for the North Pacific Ocean area immediately adjacent to the West Coast of the United States. Figure 1 shows fog frequencies from these two sources. Fog frequencies in [6] are a maximum on or near shore and decrease westward, while [3] shows a reversal of this gradient.

Figure 2 compares the climatologies of [3] and [5] for the area covered by [5]. Reference [5] is an environmental study prepared by the Naval Weather Service Detachment, Asheville, North Carolina by direction of

The Commander, Naval Weather Service Command for the Commanding Officer, Chesapeake Division, Naval Facilities Engineering Command. The area covered is from 35-45N and 140-160W as well as Ocean Weather Stations Papa and November. Among other products, [5] includes fog occurrence statistics for the area and the two ships. There are relative differences in the frequencies of marine fog in the two sources with a general lack of detail in [3] by comparison. Further, it is noted that [3] shows the percentage frequency of occurrence of fog increasing from west to east along 40N while [5] indicates that the frequency of fog occurrence decreases from west to east throughout the area. A summarizing statement in [5] says, "as in other seasons, best conditions prevail in southern and eastern parts of the area during summer." Thus, there is an implied contradiction between [3] and [5] in the subject area.

The two statistics generally used to express the climatological occurrence of fog in a specified area are percentage frequency (100 times the number of observations with fog divided by the total number of observations) and the number of days with fog. (A fog day has at least one observation reporting fog.) The percentage frequency measure, in general, maximizes the value of fog occurrence. For example, if 50 reports out of 100 indicate fog, giving a 50 percent frequency, then it is implied that fog existed 50 percent of the time represented by the 100 reports. However, it would

be reasonable to expect that some of the 50 reports of fog would not have had a continuous occurrence of fog during their representative periods. Therefore, the true frequency of fog occurrence would be something less than 50 percent in this case. Thus, the existence of fog at a synoptic reporting time does not necessarily reflect the weather during the entire period represented by the synoptic report. This period is six hours prior to observation time for the main synoptics and three hours for the intermediate synoptics. The Synoptic Code Manual [9] gives these and other details on the coding procedures and definitions necessary for understanding synoptic weather reports.

The days-with-fog method must be associated with the mean duration of fog in order to obtain a meaningful percentage of time that fog occurs. Land stations, even coastal land stations, have diurnal patterns which control the mean duration. This author is of the opinion that a similar diurnal pattern is not characteristic of marine observations. Supporting evidence for this opinion will be discussed in Chapter II Section F. Figure 3, taken from [3], apparently was utilized to assist in generating the climatological fog frequencies presented in that publication. Basis for the curves in Figure 3 is stated in [3] to be data from 20 United States Air Force Stations (presumably land stations). Because of the differing diurnal patterns

of land and marine areas, application of this figure to marine data is seriously questioned.

Other works, relating fog frequency to meteorological and oceanographic parameters, have given some insight into the differences between marine and continental fog [10], [11], [12], [13], [14], but the diurnal cycle is generally not addressed in these studies.

In light of the apparent shortcomings of existing marine-fog frequency climatologies, coupled with the current activity and interest in fog-related studies and operational applications, a new approach to generating a fog frequency climatology appears warranted.

B. OBJECTIVES

The primary objective of this study was to develop an improved method of converting an historical data base composed of synoptic ship reports, assumed random in time and space, into a climatology of fog frequencies. An accurate fog frequency climatology would be of significant value in the selection of areas for short or long-range Navy sea and air operations dependent on good visibility for success. Also, ship routing procedures utilize fog frequency climatology as an important parameter. Further, the best possible fog frequency climatology is needed as a prime parameter in a marine fog forecast model. Proper utilization of such forecasts would markedly reduce the loss of life and revenue related to low-visibility operations [1].

The secondary objective of this study was to develop a prototype climatology of fog frequency from the developed methods, comparing it to existing climatologies, as well as to frequencies derived from the "fog-days" and "percent-reports" methods. The data base was selected with a view toward adequately demonstrating the use of the methodology presented here.

C. DATA

The data base for the prototype climatology study of fog frequencies is ten years (1963-72) of North Pacific Ocean marine synoptic observations on magnetic tape for the month of July, numbering 242,084 reports. These observations are from moving ships that normally report no oftener than once each six hours and frequently only once every 12 or 24 hours. Due to the characteristic transitory nature and varying reporting intervals of this information, there is no way of establishing continuous records of any weather phenomenon for a fixed location. The data, provided by the Naval Weather Service Detachment, Asheville, North Carolina, were extracted from the historical data file known as Tape Data Family -11 (TDF-11), Surface Marine Observations. Since TDF-11 has gone through quality checks during assemblage, no quality control was applied locally other than the elimination of reports outside the geographical limits of 20 - 60N, 180 - 110W.

Additional magnetic tape data for Ocean Station Vessels (OSV) Sierra (48N162E), Quebec (43N167W), Papa (50N145W) and November (30N140W) were obtained and utilized in the development and verification of the method for determining the occurrence and duration of fog episodes. Also, microfilm copies of OSV observation log forms, which provide nearly complete chronological data, were obtained from Asheville.

II. PROCEDURES

A. DEVELOPMENT OF THE SSR SCHEME

This section outlines the development and nature of a scheme which synthesizes certain elements (or code groups) in the ship's surface synoptic reports for the purpose of assessing climatological frequencies of marine fog. The "scheme" developed in this study is also referred to as the "SSR scheme" (or, variously "method" or "program") hereafter. The original format of the SSR scheme, Table I, is based on the meteorological reasoning and experience of the author. A liberal interpretation of the guidelines and procedures provided by the Synoptic Code Manual [9] were utilized, where applicable. Table II shows the modified scheme format, as applied in this study, to determine fog occurrence and duration. The modified format resulted from adjustments made to the original version, as based on a limited verification of tests on OSVs, discussed in more detail in Section C of this Chapter.

The SSR program has two basic functions. First, it determines whether a ship's synoptic weather report indicates the occurrence of fog at observation time or during the prior three or six hours. Occurrence of fog of any duration or intensity during this time interval classifies the report as a fogger, absence of such fog gives the report a

classification of nonfogger, using terminology introduced by [10]. Second, those reports identified as foggers are evaluated for duration of fog through consideration of their present weather, past weather and visibility code numbers according to Table II. Each report considered, fogger or nonfogger, is assigned a representative time duration, six hours for main synoptics (SM) and three hours for intermediate synoptics (SI). A running total of time covered by the reports and period of fog duration as assigned by the SSR program is kept for each one-degree latitude/longitude section of the subject area. After all available data have been considered and assigned to their appropriate area, the information is converted to the percentage-of-time that fog occurs.

The SSR scheme includes 16 possible fogger combinations of present weather, past weather and visibility, plus the nonfogger category, for a total of 17 categories. In a limited verification study the original scheme format of fog duration for each category (Table I) was compared to a limited sample of actual durations of fog occurrence. The latter were manually determined from microfilm copies of detailed weather logs at OSV Sierra (48N-167E) and OSV Quebec (43N-167W). The periods compared were July, August and September 1951-53 for Sierra and 1952 for Quebec. A detailed description of the verification work and results is presented in Section C of this Chapter.

B. SSR-PROGRAM DECISIONS AND LOGIC

This section is a description of decisions and the related logic--as applied to a given synoptic report--by the computerized SJR program, which is devised to assign the occurrence/non-occurrence of marine fog and its duration.

Preliminary decisions are made on the proper location and date of each report. A time duration represented by the report is based on its associated Greenwich Mean Time (GMT), namely, six hours for main synoptic (SM) at 00, 06, 12, 18 GMT and three hours for intermediate synoptics (SI) at 03, 09, 15, 21 GMT.

Identification as a fogger or non-fogger is the first major decision. A report is classified as a fogger if any one of the following codes are reported: any present weather code of 10, 11, 12, 28 or 40-49; past weather code 4; or visibility code 90, 91, 92, 93, or 94. Otherwise, the report is indicated as a non-fogger. The present weather code figures indicate fog is occurring at the station or within sight of the station at observation time or has occurred at the station in the preceding hour. Past weather 4 indicates fog has occurred at the station during the first two hours of the preceding three-hour period for SIs or the first five hours during the preceding six-hour period for SMs. Visibility code figures of 94 or less indicate a reduction of visibility to one kilometer or its equivalents, namely 5/8 statute mile or 1,100 yards. The

visibility criterion of one kilometer or less was chosen as an appropriate value to represent those fog cases where precipitation (drizzle, rain/snow, showers, thunderstorms) occurring simultaneously with fog precluded the coding of fog for present or past weather.

There follows a discussion of the general procedures for selection of an observation as a fogger and the assignment of fog duration.

Present weather is the first parameter checked. Meeting the required fogger criterion for present weather gives information relative to the hour up to and including observation time. Further consideration must be given to the past weather before assigning a fog duration. Past weather is the second parameter checked. The report having failed the present weather criterion does not mean that fog was absent during the first two or five hours of the SI or SM period, respectively. If the report is identified as a fogger based on its past weather the existing visibility is checked. Reduced visibility will result in a larger fog duration being assigned by the scheme. The last check made, assuming the present and past weather criteria have not been met, is for reduced visibility, (< 1 hour) code numbers 90, 91, 92, 93 or 94. If the report is identified as a fogger based on its visibility the past weather is checked. Past weather code numbers 2, 5 and 6 will result in a larger fog duration being assigned by the scheme.

Table I shows the 17 categories of the SSR scheme in the original format. Some preliminary explanation and definitions are offered as aids in clarifying the SSR-scheme category descriptions. Synoptic reports are representative of the weather at the time of observation as well as the synoptic period prior to observation time, namely three hours for SIs or six hours for SMs. The present weather code figure, in general, reports the most significant weather phenomenon occurring at the time of observation or within the last hour. The past weather code figure reports the general character of the weather during the preceding two- or five-hour period. A general specification on the combined present and past weather codes is that, together they give as complete a description as possible of the weather occurring during the report period.

The duration of fog credited by the SSR program to each fogger report is indicated for each category in Table I. In some cases, more than one past weather code number is indicated in a specific category. For instance, although category 3 includes past weather 4 (fog) and 5 (drizzle), there is no reference to a required present weather code number, but visibility must be reduced to less than or equal to the upper limit of visibility allowed when reporting fog, as specified by the Synoptic Code Manual [9]. The reduced visibility in this case is taken to imply that fog is

occurring with whatever phenomenon is being reported as present weather, most likely some form of precipitation.

The past weather of 4, 5 and 6 (rain) are considered to represent the expected sequence of weather phenomena which would occur as a fog regime ends, in association with the increased thickness of the layer under the inversion or increased instability. An increase in the thickness of the sub-inversion layer is often accompanied by a lifting of the fog to low stratus. This effect, coupled with radiational cooling at the layer top, can result in sufficient vertical motion to allow droplet growth to drizzle/light rain sizes. Increased instability in the cloud layer may lead to a complete dissipation of fog, but in the dissipation process a period of drizzle/light rain can occur if the original fog layer is of adequate thickness. Considering the stated progression of weather as a fog regime ends during a three/six hour period, all three types of weather (fog, drizzle, rain) are possible. Knowing that only one type can be reported in past weather it is considered highly probable that with an existing reduced visibility, taken as an indication of fog occurring at observation time, there may also have been fog occurring during the preceding three- or six-hour period. Therefore, it is felt that past weather codes 4 and 5 or 6 can be used in a single category. Explanations of the original scheme categories follow.

Category 1 represents present weather codes 40-49 with past weather code 4 (fog) or 5 (drizzle) and no visibility criterion. Thus, the category indicates fog at the time of observation, with or without fog in the past hour, plus fog or drizzle being the most representative description of the remainder of the report period. In general, category 1 cases represent periods of continuous fog for the representative synoptic period. The original SSR-program format credits category 1 foggers with three or six hours of fog.

Category 2 represents present weather codes 10, 11 or 12 with past weather 4 or 5. These code figures indicate occurrence of light fog with the same past weather reasoning as category 1. The SSR-scheme format credits category 2 foggers with three or six hours of fog.

Category 3 represents those cases where the present weather code indicates a phenomenon other than fog but has past weather 4 or 5 and meets the reduced visibility criterion. This is intended to identify cases of fog occurring with a stable-type of precipitation. The original scheme format credits category 3 foggers with three or six hours of fog.

Category 4 represents present weather code 28 which indicates fog has occurred at the station during the last hour but not at the time of observation, with past weather 4, 5 or 6. Because fog is not occurring at observation time and

because some precipitation may have occurred during the preceding synoptic period, the character of the fog is considered less continuous. The original SSR-scheme format credits category 4 foggers with two and one-half or five hours of fog.

Category 5 represents cases of present weather codes 40-49 but with past weather 6. The occurrence of rain during the preceding period indicates the stability factor may not be favorable for continuous fog occurrence. The original SSR-program format credits category 5 with two and one-half or five hours of fog.

Category 6 represents light fog with past weather 6. The scheme handles category 6 in the same manner as category 5.

Category 7 represents those cases where the present weather code indicates phenomenon other than fog with past weather 6 and visibility codes of 90-94. This is similar to category 3, but with a past weather code less indicative of fog. The original SSR-scheme format credits category 7 with two and one-half or five hours of fog.

Category 8 represents cases of present weather codes 40-49 with past weather code 2 (clouds cover more than one-half the celestial dome throughout the period). Experience has shown a tendency for observers to code past weather as code figure 2 when fog is reported as present weather and has been occurring throughout the period. This coding

procedure apparently results from an interpretation of Chap. B4, Para. 3.4.1 of the Synoptic Code Manual [9] to mean that the same weather phenomenon for both present and past weather should not be recorded.

> 3.4.1 When precipitation, fog, ice fog, dust storm, sand storm, or storm of blowing snow is reported for <u>WW</u> the same phenomenon will also be reported for <u>W</u> only when it <u>best represents</u> the general character of the weather which occurred throughout the 5- (or 2-) hour period ending one hour prior to the time of observation.

The original SSR-scheme format credits category 8 with two or four hours of fog.

Category 9 represents light fog with past weather 2, a situation similar to category 8. The original SSR-scheme format credits category 9 with two or four hours of fog.

Category 10 represents those cases where a phenomenon other than fog is reported for present weather with past weather 2 and with visibility codes of 90-94. This is similar in design to categories 3 and 7 but with a past weather code less definitive of fog occurrence. The original SSR-scheme format credits category 10 with two or four hours of fog.

Category 11 represents present weather code 28 (fog has occurred during the last hour) with past weather 2. Category 11 is similar to category 4 but with a past weather code that is less indicative of fog. The original SSR-scheme format credits category 11 with one and one-half or three hours of fog.

Category 12 represents those cases where no fog or restriction to visibility has occurred in the past hour but past weather 4 indicates fog is the best description of the previous two- or five-hour period. The original SSR-scheme format credits category 12 with one and one-half or three hours of fog.

Category 13 represents those cases where present weather codes 40-49 are reported. This implies that fog is occurring at the station or can be observed at a distance from the station at the time of observation. The past weather code is not one that indicates, directly or indirectly, the occurrence of fog in the previous two or five hours. A visibility check is immaterial because present weather code figures 40-49 are restricted to visibility of codes numbers 94 or less. The original SSR-scheme format credits category 13 with one or two hours of fog.

Category 14 represents the cases of light fog occurrence with no past weather indication of fog. The original SSR-scheme format credits one or two hours of fog to category 14.

Category 15 represents those cases where a phenomenon other than fog is reported for present weather, with no indication of fog given in the past weather, but a visibility code figure 90-94 is reported. This is intended to identify those cases where fog and precipitation are occurring at the time of observation. Due to reporting procedure there is no way, other than the reduced visibility, that fog can

be indicated because of the prerequisite to report the higher code figure. (See reference [9], paragraph 2.4.1.) The original SSR-scheme format credits category 15 with one or two hours of fog.

Category 16 represents those cases where present weather code 28 (fog has occurred during the last hour) is reported but no past weather code indicative of fog is reported. The original SSR-scheme format credits category 16 with one-half or one hour of fog.

Category 17 represents all cases of non-foggers. Nothing in the report's present or past weather or visibility codes can be interpreted to indicate the occurrence of fog at any time during the representative period.

C. TESTING THE ORIGINAL SSR-SCHEME FORMAT

Following the formulation of the original SSR-scheme format, observations forms on microfilm and synoptic reports on magnetic tape for OSVs Sierra (48N162E) and Quebec (43N167W)[1] were utilized to test the validity of each of the SSR-scheme categories. The observation forms provide, for a single location, a continuous record of weather phenomena, by indicating starting and stopping times, from which actual durations of fog episodes can be determined. This information was manually extracted from the microfilm, and the

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[1]Obtained from National Climatic Center, via the Naval Weather Service Detachment, Asheville, N. C.

actual frequency of fog, as the percentage of time that fog occurred, was established.

The test period is July, August and September of 1951-53 for Sierra and 1952 for Quebec. Thus the total test period represents 12 months of nearly continuous data,each day of which comprises four main synoptics and four intermediate synoptics. OSVs are occasionally required to leave station for search and rescue or other special missions; this results in some breaks in station records. During the test period, of the 8,832 possible hours, 561 hours (about 7%) were not covered by reports.

To test the original SSR-scheme format, a comparison was made between the actual frequency of fog occurrence as determinted from the detailed observation forms, and the frequency of fog occurrence as determined by the SSR program when applied only to the synoptic report file. The frequencies of fog occurrence, based on the author's interpretation of Figure 3, called fog-days method, and the percent-of-reports-with-fog method, were also computed for comparison to the scheme frequency. Table III shows the results of this limited testing. The original SSR scheme gives the closest approximations to the actual conditions in all months except September 1952 and 1953 for OSV Sierra when the percent-reports method is best. The variation between the original SSR scheme and the actual frequencies is equal to or less than five percent for each of the 12 test months with a mean error of two percent. This compares to seven out of 12

months and five out of 12 months with average errors of seven percent for both the percent-reports and fog-days methods, respectively.

Although the results of the above comparison indicated greater skill for the original SSR scheme compared to the other two methods, there remained the question of how each category in the scheme performed. The results of a test, on OSV Sierra and Quebec data, to satisfy this requirement, is shown in Table IV. It is to be noted that the test was run on main synoptic (SM) reports only. The initial SSR-program development had been made while working with the OSV records which are composed of both SMs and SIs, that is, a synoptic report every three hours. However, when application to random-ship synoptic records was considered, it was realized that the majority of the random reports would be SMs. Therefore, the scheme was tested with respect to six-hour periods without regard to the intervening intermediate synoptic reports.

Only those periods were sampled for which there were both synoptic reports and observation logs. The seven percent of the time that station records are incomplete (100 SMs) are included in category 17, non-foggers. The inclusion of missing data periods was considered as periods of no-fog occurrence and no fog was indicated by the scheme. Handling the missing data periods in this manner does not enhance the scheme performance figures because all of the verification skill is reflected in the performance of the first 16

categories. That is, the verification reflects the skill in handling cases of fog, not the cases of no fog.

Table IV shows, for each category, the verification statistics for synoptic reports in which the scheme-credited fog time is less than and greater than the actual fog time as well as the overall performance of each category, the latter to include a count of all cases with and without error. Negative values indicate an under allotment of fog time by the original SSR program. Category one, for example, occurred 227 times. The scheme indicated 182.2 hours more of fog time than the actual fog time logged. This resulted in an average overestimate of fog time by the scheme of 0.8 hour per case.

D. MODIFICATION OF THE ORIGINAL SSR-SCHEME FORMAT

Based on the verification results in Table IV, the original SSR-scheme format was modified to that shown in Table II. Specifically, scheme credit of fog time for each representative three-/six-hour period was reduced by .1/.2 hours for category 1; by .2/.4 hours for categories 2, 3 and 4; by .3/.6 hours for category 9; and by .4/.8 hours for category 7; while the scheme credit for category 12 was increased by .5/1.0 hours.

The modified SSR-scheme format was then used to re-evaluate the 12 months of data from OSVs Sierra and Quebec. Table V shows the performance of the SSR scheme in the original and modified formats. It is to be noted that of

the 12 test months, six indicate a more accurate fog frequency specification under the modified format, with a total cumulative improvement of 12 percent. Four months indicate poorer results by the modified scheme with a cumulative error of 5 percent. Overall, the modified format gives a 7 percent improvement over the original format.

E. INTERPRETATION OF CATEGORIES WITHIN THE SSR SCHEME

Various points of interest can be gleaned from the verification of categories, Table IV. For instance, it may be noted that the entire test period of 12 months, each with 31 days and four SMs per day, represents a total test base of 1,488 possible SMs. As stated earlier, for seven percent of the period the OSV records were not available for verification. This equates to 100 missing SMs, leaving an actual test base of 1,388 SMs. Of this number the scheme identifies 431 (31 percent) as reports of fog. The 19 cases of category 15 indicated in Table IV resulted from incomplete synoptic reports; that is, present weather, past weather and visibility were missing. Since missing visibility data are encoded as zeros, the scheme inadvertently considered these as low-visibility reports. The 19 cases were included in category 17, non-foggers, when the test was run that generated Table VI.

Examining those categories (Table VI) that are identified as fog reports based on visibility (categories 3, 7, 10, 15), the following points can be made. There are 47 such

cases of scheme-identified fog reports, or about 11 percent of all the fog reports in Table VI. This represents a total period of 282 (or 6 x 47) hours. Of this period the scheme indicates 235.8 hours of fog, while the actual duration of fog was 202.6 hours. Within this general class of visibility-related fog reports, category 7 is of particular interest. The 17 cases of category 7 (4 percent of the total fog reports) represents 102 hours of total duration of which the scheme indicates 71.4 hours of fog and the actual logs show 54.9 hours of fog. It is to be noted that category 7 makes no check of present weather nor does it have a past weather code number that would routinely identify a report as one with fog. Therefore, while the scheme does slightly overestimate the fog duration in this category, it must be credited with indicating the 54.9 hours properly. This fog time would not be detected by any other known existing method for identifying fog in a synoptic report.

Category 3 results can be evaluated in a similar manner. A basic difference does exist between categories 3 and 7, that is category 3 does include some reports with past weather code number 4 (fog). Therefore, those cases with past weather fog indicated could be identified as having fog during the first two or five hours only of the SI/SM represented period. A detailed check of the category cases has not been made at this time; therefore, the number of category 3 cases with past weather code number 4 (fog) as compared to past weather code number 5 (drizzle) is not known.

The inclusion of past weather code number 6 (rain) and past weather code number 2 (clouds covering more than one-half the celestial dome throughout the period) are worthy of discussion. First, it should be noted that the consideration of these past weather descriptors are only considered after the report has been selected as a fog report because of its present weather or reduced visibility. Experience gained by reviewing thousands of synoptic reports, and related observation forms from OSVs, have shown that past weather code numbers 2 and 6 are frequently reported with various present weather and visibility code numbers during periods of actual continuous fog occurrence. This appears to result from an effort by the individual originating the synoptic report to follow the guidelines set down in the Synoptic Code Manual [9]. For instance, during a prolonged period of fog during which no other weather phenomenon occurs, the observer has only fog to report as present and past weather. But [9], in paragraph 3.4.1, quoted earlier, implies a need for a description better than just fog and more fog. It leaves open to personal judgement the choice of reporting past weather as code number 4 or as 2 in an attempt to describe a case where the fog was continuous throughout the period and therefore more than one-half the sky was covered throughout the period. This continuous coverage fact is not indicated by past weather code number 4 (fog).

The inclusion of precipitation in past weather may not be objectionable if it is restricted to drizzle. Allowing past weather 6 in scheme category 4 may be questionable. However, if properly used, past weather code number 6 (rain) does not include rain showers (past weather code number 8) or thunderstorms (past weather code number 9). Therefore, exclusion of shower-type rain should eliminate reports from those areas marked by instability, considered by this author to be unfavorable for any significant fog occurrence. Furthermore, as stated earlier, past weather code number 6 (rain) is only considered after the report has been identified as a fogger by some other parameter. In categories 5 6 and 7 it has the effect of reducing the scheme-alloted fog time that would have been assigned to the fog-report identifying parameter, had the past weather been code number 4 (fog) or code number 5 (drizzle). The earlier evaluation of category 7 gives support to this approach.

With the SSR-scheme format modified as reflected in Table II and the verification by category as indicated in Table VI it was felt that the scheme was tuned as well as could be expected considering the limited test cases available for verification. Therefore, it was decided to apply the modified SSR scheme to a ten-year July data base (1962-73) for the North Pacific Ocean area of 20-60N, 180 to 110W.

F. DIURNAL DISTRIBUTION OF MARINE FOG

The fog-days method of determining the frequency of fog occurrence, as used in [3], was questioned in an earlier

section because of the apparent application of a land-derived frequency table, shown here in Figure 3. It was also noted that the occurrence of marine fog had been related to various environmental parameters, which in this author's opinion, were not directly related to the day/night heating and cooling pattern typical of land areas. Rather, it is believed that diurnal fog maximum and minimum occurrences in marine areas are a seasonal-/climatic-regime variation which is reflected as a seasonally changing diurnal pattern.

One of the first problems addressed in developing this aspect of the study was the diurnal variation of marine fog. The Greenwich Mean Time (GMT) of all synoptic reports was converted to the local mean time (LMT) appropriate to their geographical position. Figures 4 and 5 show the diurnal distribution for two Ocean Station Vessels (OSV) in the North Pacific Ocean area. Figure 4 based on six years of synoptic reports (1963-68) (50N 145W) shows a minimum occurrence of fog at 0200 LMT during July, at 1100 LMT during August, and at 2300 LMT during September. The occurrence of fog at the eight local times, that relate to the eight synoptic reporting times (00, 03, 06, 09, 12, 15, 18, 21 GMT), reflects the percentage of synoptic reports with fog (according to modified SSR scheme) made at each report time. The distribution relative to GMT, as given in [5], and included in Figure 4 represents the data in four time periods vice the eight observation times. Adjusting the GMTs of [5] to LMTs by

subtracting ten hours gives excellent agreement between the two sources on the monthly diurnal pattern, although the frequencies differ considerably in magnitude.

Figure 5 is a more detailed distribution of fog occurrence for OSV Sierra (48N-162E) for July 1950-52, and August and September 1950-51. The frequency of fog occurrence for each local hour throughout the 24-hour day is shown. The percentage of fog occurrence for each local hour was obtained from the OSV observation forms on which the beginnings and endings of all weather phenomena are logged. Recognizing that the period for OSV Sierra is only two or three years for each of the three months, it is still offered as supporting evidence of the changing diurnal pattern. July shows a 1400 local minimum, August a 1000 local minimum and September a 0400 local minimum. While a monthly shift of diurnal minimums is once again evident, the two cases do not show minimums occurring at the same local time for a given month. It is this author's opinion that the diurnal shift of minimum fog occurrence is a reflection of the general circulation pattern, both oceanic and atmospheric, and therefore both the season and geographical position of the observation point will have an influence. In all cases shown here as well as those indicated for the remainder of the year in the areas covered by [5] and a similar Atlantic study [15], the diurnal range of frequency of fog occurrence is small relative to the typical land station diurnal spread. Based on these findings, the diurnal effects on fog occurrence are dismissed when

evaluating the data base for input into the prototype fog frequency climatology. That is, all reports of fog, regardless of LMT, were considered of equal weight in determining the frequency of fog occurrence.

G. TESTING OTHER WEATHER PARAMETERS AS INDICATORS OF FOG

In addition to the combinations of present weather, past weather and visibility currently reflected in the 16 fogger categories of the SSR scheme, several other combinations were tested and compared to the actual durations of fog as determined from the observation logs. For example, drizzle is considered likely to occur during a fog regime. It is not currently considered as an identifier of a fogger, only as a modifier of fog time credited to a report that is already considered a fogger because of its present weather or visibility.

The use of drizzle in a report as a fog identifier was tested in two categories. First, drizzle was considered as an identifier of fog when reported as present weather with or without drizzle in the past weather. For this category the visibility range allowed was from 1 km up to 4 km (code numbers 95, 96). The category was defined in this manner so that it would be exclusive, that is, it would not overlap existing visibility categories. No past weather code numbers were allowed to influence this category. The obvious result was an increase in the indicated fog frequencies for all three methods, SSR-scheme, percent-of-reports and

fog days. However, when the periods of the reports identified as foggers by the above drizzle category were compared to the actual observation logs of the ocean station vessels it was found that fog was not actually being logged. Thus, this category was not used.

The second drizzle category test keyed on drizzle in the past weather code. This category was handled exactly like category 12, past weather code number 4 (fog), but with no checks on either present weather or visibility. The results of this test were the same as the first, the frequencies increased, but when compared to the actual logs the drizzle-defined foggers were not occurring during actual fog episodes. Again, this category was dismissed from use in the scheme.

During the SSR-scheme development only OSV data were being utilized. The OSV data provided the nearly continuous file of synoptic reports at three-hour intervals plus the observation forms from which continuous records of fog occurrence can be determined for verification purposes. However, as noted in [5] and elsewhere, there can be differences in OSV reporting procedures, as evidenced by the station-ship reports and random-ship reports showing differing observation and encoding characteristics. Related to this fact is the question as to whether a fog-identification scheme developed from ocean station vessels (or their equivalent) manned by trained observers, can provide usable information when applied to data from random ships, manned by observers of widely varying skills. To answer this question a test data base

was needed that provided both the continuous records and random records for the same period and location. Ocean Station Vessel Papa and the surrounding area for the period 1963-68 was the only such data base readily available.

In this test two basic questions were posed. First, what would a sample of random ships around OSV Papa indicate relative to fog frequency and second, could a fair-weather bias or any other bias be detected in the random-ship reports. Fair-weather bias implies random ships may have a tendency to seek out fair weather; therefore, their reports would indicate reduced frequencies of poor weather conditions. The test was conducted on a data base drawn from a 2 x 2 degree latitude/longitude square centered on Ocean Station Papa (50N 145W). Table VII shows the comparative fog frequencies as determined by the SSR program for Ocean Station Papa and the surrounding area. The surrounding area data base <u>does not</u> include the OSV reports. The actual occurrence of fog is also indicated; however, due to observation logging procedures at Ocean Station Papa some adjustments were required for the following reason. The observation logs for Papa do not indicate the occurrence of light fog (visibility code numbers 95 or greater), even though it apparently occurred, as determined from the synoptic reports. Therefore, to obtain a usable frequency value for the "actual fog occurrences," it was necessary to modify the Papa observation logs. To accomplish this the synoptic report values of present weather, past weather and visibility were utilized, in accordance with

the SSR program (original format), to adjust the observation logs. Because modifications, using scheme criteria, were made to entries in Papa's observation logs, no use is made of them to verify the scheme itself. Any reference to the actual frequency values at Papa should be made with the above in mind.

The absence of actual fog frequencies does not invalidate the comparison between frequencies from Papa and the random reports in the surrounding area as determined from the SSR scheme. Table VII indicates that while there are variations between Station Papa and random-ship fog frequencies on a year-to-year basis the compatibility of results is good for a multiple-year data base. This suggests that, given a data base with suitable duration to qualify for meaningful climatology, the scheme-generated fog frequencies derived from random-ship reports become credible. As noted earlier a ten-year data base was chosen for use in this study.

The last column of Table VII represents the frequency of fog occurrence at Papa when tested only at the time that random reports were available in the test area. This is an attempt to detect "fair-weather" bias on the part of random ships. It would be considered a "fair-weather" bias if Papa's fog frequency at the times of the random reports was significantly lower than Papa's complete-month fog frequency. Table VII shows the average difference to be insignificant; however, due to the limited testing the results are considered inconclusive. It was not considered pertinent at the time of this study to further pursue the "fair-weather" bias question.

H. ANALYSIS PROCEDURES

Having developed the SSR scheme and modified its format to best fit the data base available for verification it was applied to a ten-year data base of random-ship synoptic reports (July 1963-72).

The reports were evaluated by the scheme and assigned to their respective 1 x 1 degree latitude/longitude areas. Cumulative totals for representative time, scheme-assigned fog time, number of reports, number of reports with fog and days with fog were tallied for each area. To allow for shorter running computer programs, each 10 x 10 degree latitude/longitude area was run separately and the resulting fog frequencies were retained on punchcards. After completing such computer runs for the entire eastern North Pacific Ocean for which data were available (20-60N, 180-110W), the resulting frequencies were ready for production as analyzed charts.

In order to produce the best possible climatology it was felt that some sort of areal smoothing should be applied to the 1 x 1 degree areas. In addition to providing a more esthetic product, the smoothing procedure was designed to give the maximum weight to those areas in which the largest number of reports were available.

The equation used to smooth the data is:

$$F^*_{i,j} = (4FR_{i,j} + FR_{i-1,j} + FR_{i+1,j} + F\,R_{i,j-1} + F\,R_{i,j+1}) \,/\, (4R_{i,j} + R_{i-1,j} + R_{i+1,j} + R_{i,j-1} + R_{i,j+1})$$

where F^* is the nth smoothed frequency, F is the n-1 frequency, R is the number of reports, and i and j have their normal grid location meanings.

The smoother was applied twice to each of the data sets of SSR-scheme frequency, percent-reports frequency and fog-days frequency. Following two smoothings, the data sets were analyzed by use of the program CONTUR, a system routine in the general purpose Naval Postgraduate School library, which produces analyzed charts on a CALCOMP plotter.

III. RESULTS AND CONCLUSIONS

A. COMPARISON OF THE SSR-SCHEME RESULTS TO OTHER CLIMATOLOGIES

Figure 6 is the prototype climatological fog frequency produced by the SSR program for the month of July, eastern North Pacific Ocean area. Salient features of interest include an east/west axis of maximum fog occurrence near 46N, which extends from the mid-Pacific eastward to near 135W. Near the west coast of the United States the increased fog occurrence is related to the well-known upwelling of the area. It is to be noted that for the area not influenced by upwelling, the southernmost extent of the fog area, as delineated by the five percent isoline, occurs close to 34N near the date line. Progressing eastward from 180 degrees there is a nearly uniform northward trend of all isolines. The northernmost position (near 40N) of the five percent isoline nearly coincides with the east-west axis of the mean subtropical high in the eastern North Pacific Ocean area.

For comparison purposes Figures 7, 8, and 9 are included. Figure 7 is the fog frequency climatology taken from [3]. In general it reflects little detail and considerably lower frequencies than the SSR-scheme derived values. In some areas it is in marked disagreement with the climatology developed in this study, and especially so along the west coast of the United States, where [3] was earlier shown to

disagree with the regional climatology in [6]. A significant difference in fog distribution exists between Figures 6 and 7 along the lower-latitude boundary of fog as defined by the five percent isoline.

Figure 8 presents the average frequencies of fog occurrence resulting from the percent-of-reports-with-fog method. The SSR program was used to identify observations classified as foggers. In general, this reflects the same pattern as the SSR-scheme climatology but as indicated earlier the method gives frequencies that are higher than or equal to the SSR scheme or actual frequencies.

Figure 9 presents the climatological frequencies of fog that result from using Figure 3 and an interpretation of the fog-days method in [3]. The SSR program was used to identify observation days classified as foggers. The results of this method appear to indicate a significant reduction in the fog occurrence frequencies compared to the other climatologies presented here. The results in Figure 9 are considered unrealistic and thus unsatisfactory for operational use.

B. DISTRIBUTION OF SYNOPTIC REPORTS

Figure 10 is an analysis of the distribution of synoptic reports. Only isolines for 10, 50 and 150 reports have been drawn. In general, the major ports and shipping routes are easily identifiable. The region of maximum fog frequencies from Figure 6 coincides with the region of a minimum number of reports. To the north of the minimum-report area, above

47N in the mid-Pacific, the great circle route across the North Pacific is detectable. South of the report minimum area, a belt of higher report counts reflects ship traffic skirting the southern boundary of the area of high frequency of fog, shown in Figure 6. This belt of high report count, which intersects the date line near 35N and angles northward to the east, corresponds very well with the SSR-scheme indicated southern boundary of high fog frequency. Ships traversing the North Pacific, which for various reasons chose to stay out of the fog, would develop such a belt of high report count if in fact the mean fog boundary was as indicated in the scheme climatology.

C. VERIFICATION OF THE SSR-SCHEME CLIMATOLOGY

To verify any type of fog frequency climatology for an oceanic area like the North Pacific, with very few locations that have any manner of continuous records, will be a difficult problem. The lack of any prior reliable fog frequencies for this area makes even the climatological intercomparisons difficult. A third problem arises from the need to utilize synoptic reports as a data base, and therefore the need for an acceptable definition of a report with fog.

One independent study, [8], gives the average hours of fog recorded at various lighthouse stations along the west coast of California. The applicability of land influenced data relative to marine fog frequencies has already been discussed. Nevertheless, with no other available records of actual hours of fog occurrence available, the lighthouse

data, taken from [8], are shown in comparison to the SSR-scheme generated fog frequencies, as derived from ship reports (Table VIII). The comparison shows the scheme frequencies in the 1 x 1 degree latitude/longitude areas along the coast line. The lighthouse frequencies are obtained by converting the average hours of fog given in [8] to percentage of time with fog. The periods of record for the lighthouse stations vary from 15 to 23 years. The comparison is considered favorable and is offered as an indication that the method developed in this study properly indicates the average fog frequencies for the region of the North Pacific Ocean close to the west coast of the United States during July. Recalling that the SSR scheme was developed to best fit verification data from mid-ocean regimes, this verification by lighthouse data seems even more significant.

D. CONCLUSIONS

Presented herein is a unique approach to deriving a marine-fog frequency climatology from historical surface-ship synoptic report files. The methodology developed attempts to utilize the full information content of such reports to generate the prototype of a representative detailed fog frequency climatology. Application to July for the eastern North Pacific Ocean area indicates accuracy and suitability for operational use beyond the existing climatologies to which the subject method is compared. An extension of the work is proposed in the next section.

It is felt that a marine-fog frequency climatology generated by the program developed in this study would be suitable for use as an input parameter to a marine-fog forecast model. Climatology generated by the SSR scheme would be a useful reference for any individual or unit required to select sites or areas of high or low frequencies of fog occurrence.

E. SUGGESTED TOPICS FOR FURTHER STUDY

1. For verification purposes, additional sources of continuous records from specific marine locations should be pursued. Investigation of data from the military radar picket stations, manned by United States Navy Ships (DERs and AGRs in the North Pacific Ocean), should be undertaken. OSVs Oboe (40N-142W), Extra (39N-153E), and Tango (29N-135E) also should be utilized as verification sources.

2. Prior to utilizing the scheme on months other than July, additional verification for the subject month should be made. The modification made to the original format indicates that monthly or seasonal coefficients, to adjust the fog time allotted by the SSR scheme, could be developed.

3. To further verify or modify individual categories in the SSR scheme, a detailed verification should be made which would show the performance of the various combinations within each category. A specific improvement in identifying fog reports by low visibility would result from checking the present weather code for those numbers that indicate heavy

precipitation at time of observation.[2] Elimination of reports of this nature would tend to remove a possible source of error in categories 3, 7, 10 and 15.

4. Further investigation of the changing diurnal patterns of fog for marine regimes should be made. For climatological purposes, the significance of a given synoptic report at a specific local mean time would appear to be inversely related to the diurnal pattern of the parameter being considered. Correlation of the relationship of various environmental parameters, as related to the diurnal pattern of fog occurrence, may give additional insight for selection of fog-related forecast parameters.

5. Detailed investigation of areas of high report count, near the west coast of United States, could be made for 0.1 degree latitude/longitude areas for further insight into the fog and low stratus situations that exist in this area.

6. The available random-ship synoptic report data base should be investigated to determine the distribution, by year, of the reports.

7. The existing SSR-scheme categories should be correlated with other parameters included in ship synoptic reports for further insight into the occurrence of fog. Such information will be of use in developing a marine-fog forecast model.

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[2] Suggested by Mr. James Zuver of Fleet Numerical Weather Central, Monterey, California.

TABLE I

Original format of the SSR scheme used to assign duration of fog, per three-hour synoptic period, as a function of present and past weather, and visibility code values in the marine synoptic report.
*Indicates that the code group is not considered in the selection of the report as a fogger or in assigning the duration of fog.

SSR-SCHEME CATEGORY	SYNOPTIC CODE VALUES			ASSIGNED HOURS OF FOG PER THREE-HOUR SYNOPTIC PERIOD
	VISIBILITY	WEATHER		
		PRESENT	PAST	
1	*	40s	4,5	3.0
2	*	10,11,12	4,5	3.0
3	90-94	*	4,5	3.0
4	*	28	4,5,6	2.5
5	*	40s	6	2.5
6	*	10,11,12	6	2.5
7	90-94	*	6	2.5
8	*	40s	2	2.0
9	*	10,11,12	2	2.0
10	90-94	*	2	2.0
11	*	28	2	1.5
12	*	*	4	1.5
13	*	40s	*	1.0
14	*	10,11,12	*	1.0
15	90-94	*	*	1.0
16	*	28	*	0.5
17	All non-foggers			0.0

TABLE II

Modified format of the SSR scheme used to assign duration of fog, per three-hour synoptic period, as a function of present and past weather, and visibility code values in the marine synoptic report.
*Indicates that the code group is not considered in the selection of the report as a fogger or in assigning the duration of fog.

SCHEME CATEGORY	SYNOPTIC CODE VALUES			ASSIGNED HOURS OF FOG PER THREE-HOUR SYNOPTIC PERIOD
	VISIBILITY	WEATHER		
		PRESENT	PAST	
1	*	40s	4,5	2.9
2	*	10,11,12	4,5	2.8
3	90-94	*	4,5	2.8
4	*	28	4,5,6	2.3
5	*	40s	6	2.5
6	*	10,11,12	6	2.5
7	90-94	*	6	2.1
8	*	40s	2	2.0
9	*	10,11,12	2	1.7
10	90-94	*	2	2.0
11	*	28	2	1.5
12	*	*	4	2.0
13	*	40s	*	1.0
14	*	10,11,12	*	1.0
15	90-94	*	*	1.0
16	*	28	*	0.5
17	All non-foggers			0

TABLE III

Comparison of the actual percentage of time that fog occurred to fog frequencies derived from three methods, for ocean stations Sierra (48N 162E) and Quebec (43N 167W).

Ocean Station Vessel	Period	Actual Time Fog Occurred (%)	Derived Fog Frequencies (%) Original SSR-Scheme Format	Percentage-of-Reports-Method	Fog-Days Method
S	July 51	31	36	42	42
S	July 52	74	78	82	83
S	July 53	43	48	55	52
Q	July 52	38	39	45	28
S	Aug 51	30	30	37	20
S	Aug 52	37	41	52	41
S	Aug 53	37	40	46	46
Q	Aug 52	21	20	29	17
S	Sept 51	7	7	8	4
S	Sept 52	15	12	17	11
S	Sept 53	22	19	21	20
Q	Sept 52	12	13	15	10

TABLE IV

Summary of category errors resulting from application of the SSR scheme in original format to the six-hourly synoptic reports from OSV Sierra (48N 162E)(July 51-53), (Aug 51-52), (Sept 51-52) and OSV Quebec (43N 167W) (July, Aug, Sept 52). The cases in each category are separated by under- and over-allotment of fog hours as well as all cases. Negative values indicate underallotment by the original SSR scheme format.

SSR-SCHEME	Time Alloted by Original SSR Scheme						Totals		
	Under Alloted			Over Alloted					
CATEGORY	No. of Cases	Hours	Average	No. of Cases	Hours	Average	No. of Cases	Hours	Average
1	0	0.0	0.00	69	182.2	2.64	227	182.2	0.80
2	0	0.0	0.00	25	68.1	2.72	62	68.1	1.10
3	0	0.0	0.00	9	24.3	2.70	29	24.3	0.84
4	6	-3.2	-0.53	3	6.0	2.00	11	2.8	0.25
5	13	-11.6	-0.89	11	27.5	2.50	25	15.9	0.64
6	7	-7.0	-1.00	3	10.7	3.57	10	3.7	0.37
7	5	-5.0	-1.00	12	35.1	2.92	17	30.1	1.77
8	4	-5.5	-1.37	10	13.3	1.33	16	7.8	0.49
9	3	-5.0	-1.67	15	40.8	2.72	18	35.8	1.99
10	0	0.0	0.00	1	4.0	4.00	1	4.0	4.00
11	0	0.0	0.00	1	1.4	1.40	1	1.4	1.40
12	61	-102.5	-1.68	42	54.0	1.29	107	-48.5	-0.45
13	1	-4.0	-4.00	0	0.0	0.00	1	-4.0	-4.00
14	0	0.0	0.00	1	2.0	2.00	1	2.0	2.00
15	2	-2.9	-1.45	17	32.8	1.93	19	29.9	1.57
16	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
17	89	-229.8	-2.58	0	0.0	0.00	943	-229.8	-0.24

TABLE V

Comparison of SSR-scheme fog frequencies from the original and modified format to the actual percentage of time with fog. The test data base consists of 12 months of synoptic reports from OSVs Sierra (48N 162E) and Quebec (43N 167W). Negative values indicate under allotment of fog by SSR scheme relative to actual occurrence.

				Actual Fog Occurrence		Fog Occurrence by SSR Scheme			
						Original Format		Modified Format	
Ocean Station	Year (19__)	Month	Hours on Station	Hours	Percent of On-Station Time(%)	Error(hrs)	Time(%)	Error(hrs)	Time(%)
S	51	Jul	732	225.8	31	34.2	36	21.2	34
S	52	Jul	735	547.3	74	25.7	78	3.5	75
S	53	Jul	681	291.1	43	32.6	8	20.9	46
Q	52	Jul	726	273.2	38	8.8	39	-3.4	37
S	51	Aug	576	173.7	30	-2.7	30	-10.1	28
S	52	Aug	699	255.6	37	28.5	41	16.7	39
S	53	Aug	672	250.3	37	17.3	40	6.3	38
Q	52	Aug	726	152.5	21	-6.7	20	-11.9	19
S	51	Sep	711	48.3	7	-0.3	7	-1.3	7
S	52	Sep	702	104.4	15	-17.3	12	-28.4	11
S	53	Sep	708	157.4	22	-23.4	19	-32.2	18
Q	52	Sep	699	81.1	12	8.9	13	4.5	12
S: nine-month mean frequencies (%)									
		Jul			49		54		52
		Aug			35		37		35
		Sep			15		13		12

TABLE VI

Summary of category errors resulting from application of the SSR scheme in modified format to the six-hourly synoptic reports from OSV Sierra (48N 162E)(July 51-53), (Aug 51-52), (Sept 51-52) and OSV Quebec (43N 167W) (July, Aug, Sept 52). The cases in each category are separated by under- and over-allotment of fog hours as well as all cases. Negative values indicate underallotment by the original SSR scheme format.

SSR-SCHEME CATEGORY	Time Alloted by Modified SSR Scheme: Under Alloted			Over Alloted			Totals		
	No. of Cases	Hours	Average	No. of Cases	Hours	Average	No. of Cases	Hours	Average
1	158	-31.6	-0.20	69	168.4	2.40	227	136.8	0.60
2	38	-15.1	-0.40	24	58.4	2.43	62	43.3	0.70
3	20	-8.0	-0.40	9	20.7	2.30	29	12.7	0.44
4	8	-6.4	-0.80	3	4.8	1.60	11	-1.6	-0.15
5	13	-11.6	-0.89	11	27.5	2.50	25	15.9	0.64
6	7	-7.0	-1.00	3	10.7	3.57	10	3.7	0.37
7	6	-9.3	-1.55	11	25.8	2.35	17	16.5	0.97
8	4	-5.5	-1.37	10	13.3	1.33	16	7.8	0.49
9	3	-6.8	-2.27	14	31.8	2.27	18	25.0	1.39
10	0	0.0	0.00	1	4.0	4.00	1	4.0	4.00
11	0	0.0	0.00	1	1.4	1.40	1	1.4	1.40
12	61	-102.5	-1.68	42	54.0	1.29	107	-48.5	-0.45
13	1	-4.0	-4.00	0	0.0	0.00	1	-4.0	-4.00
14	0	0.0	0.00	1	2.0	2.00	1	2.0	2.00
15	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
16	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
17	89	-229.8	-2.58	0	0.0	0.00	962	-229.8	-0.24

TABLE VII

Comparison of fog frequencies for July derived by the original SSR scheme format for random-ship reports and Ocean Station Papa (50N 145W) reports and from the observation logs, as adjusted (see text for explanation). The random reports are from 2 x 2 degree latitude /longitude squares centered on Papa and do not include Papa's reports.

Year (19__)	Ocean Station Papa: Actual Fog Frequencies (%)	Ocean Station Papa: SSR-Scheme Fog Frequencies: Entire Month (%)	Ocean Station Papa: SSR-Scheme Fog Frequencies: At Times of Random -Ship Reports Only (%)	Random-ship reports: SSR-Scheme Fog Frequencies (%)
63	33	26	18	19
64	13	12	15	7
65	18	16	22	13
66	29	31	24	38
67	25	22	22	22
68	18	17	26	20
63-68	23	21	21	20

TABLE VIII

Comparison of July fog frequencies at lighthouse stations, along the California Coast, to SSR-scheme derived fog frequencies from random-ship reports in the 1 x 1 degree latitude/longitude squares in which the lighthouses are located. The lighthouse data periods range from 15 to 23 years; the ships data are from the period 1963-72. Lighthouse fog frequencies are computed from the average hours of fog given in [8].

For Lighthouse Stations			For Area which includes Lighthouse Station	
Location	Average hours of fog	Fog Frequency(%)	Location	SSR-Scheme Fog Frequency (%)
Point Arguello	159.33	21	34N 120W	19
Piedras Blancas	179.61	24	35N 121W	19
Point Sur	171.88	23	36N 121W	19
Farallon Islands	96.53	13	37N 122W	16
Point Reyes	200.13	27	38N 123W	26
Point Arena	175.95	23	38N 123W	26

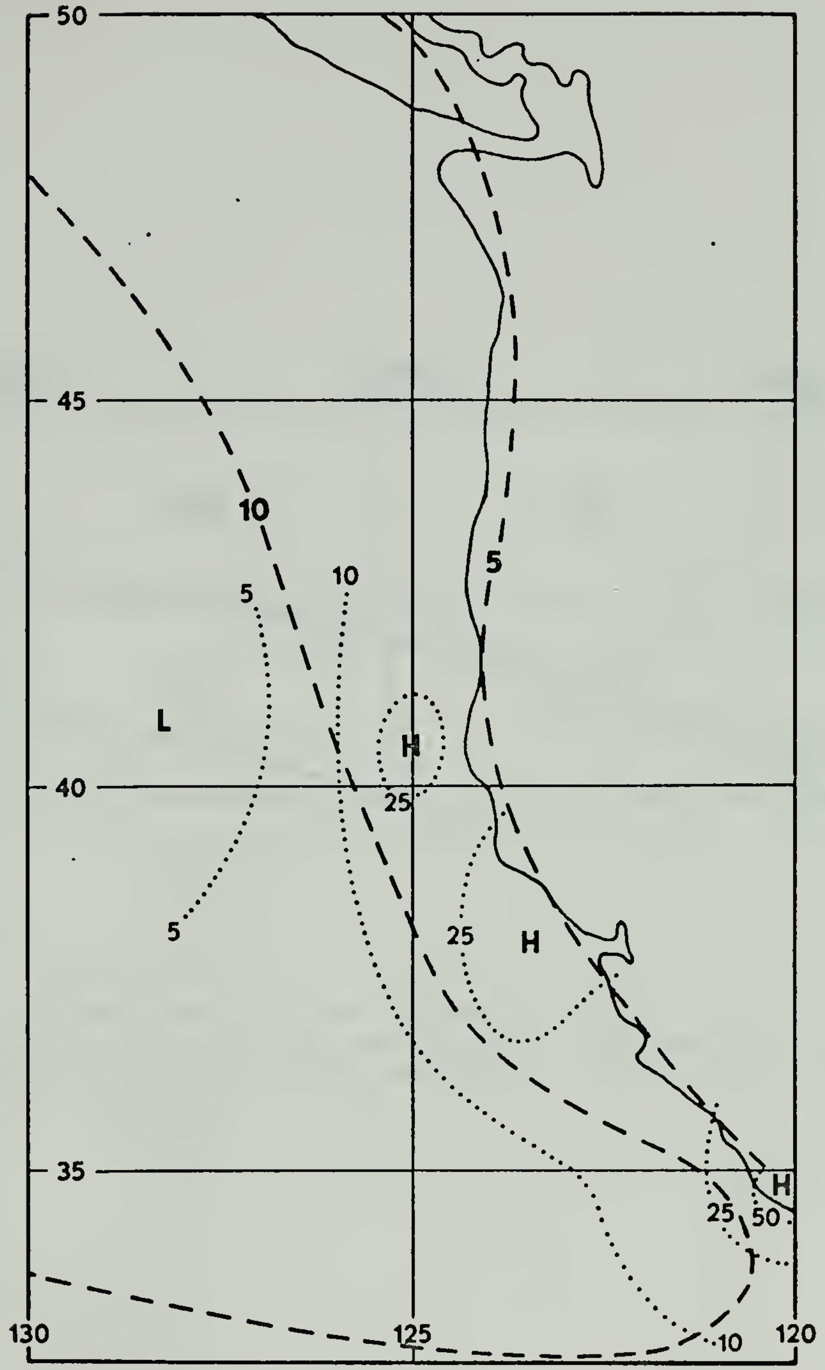

Figure 1. Comparison of two climatologies of July marine fog frequencies in the vicinity of the west coast of the United States. Dashed isolines from [3], dotted contours computed from data in [6] (in percent).

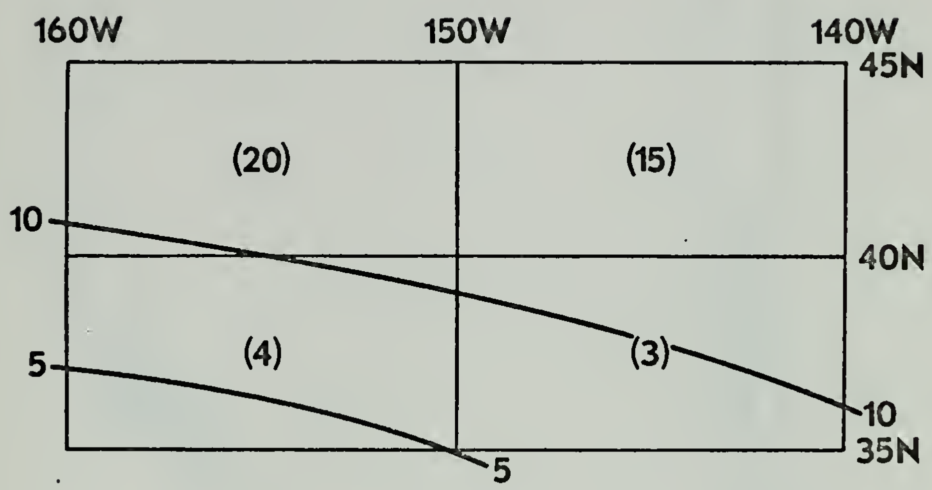

Figure 2. Comparison of two climatologies of July marine fog frequencies for a limited area of the northeast Pacific Ocean area. Frequencies in parentheses from [5], isolines from [3] (in percent).

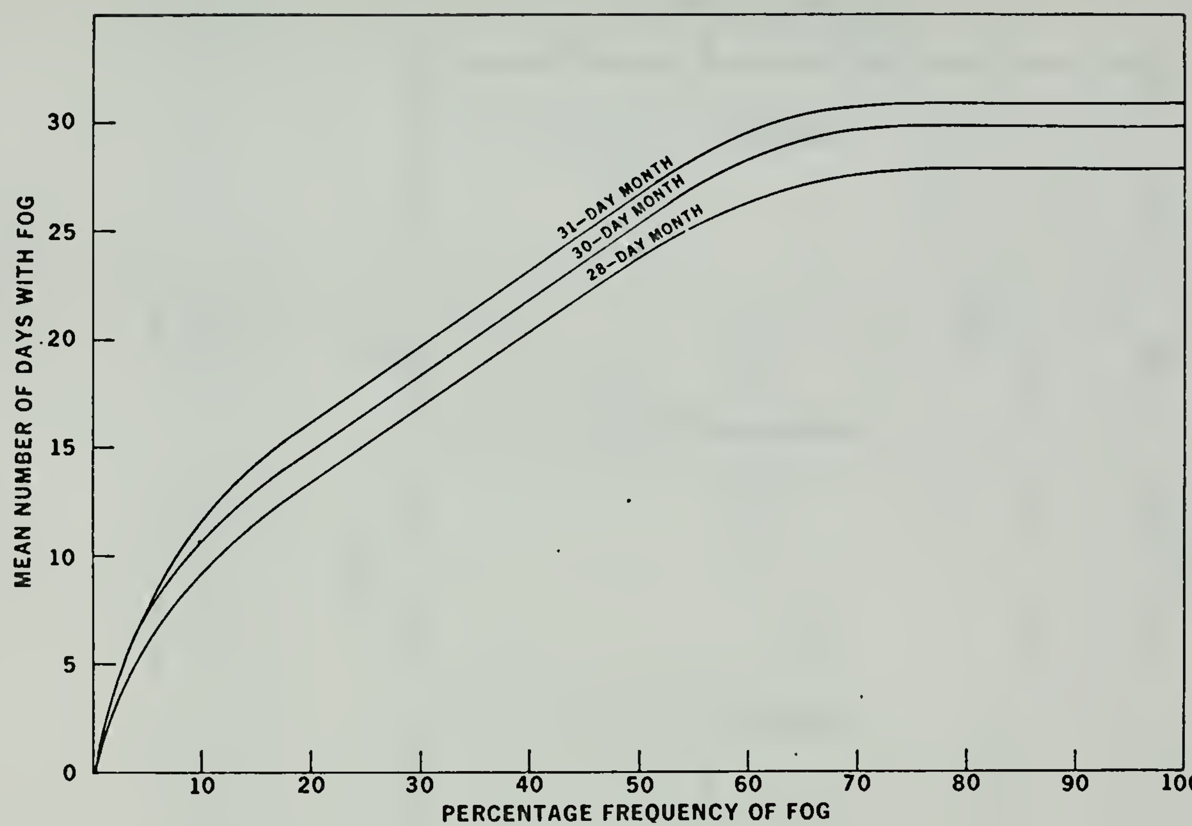

Figure 3. Conversion from monthly mean number of days with fog to percentage frequency of fog, from [3].

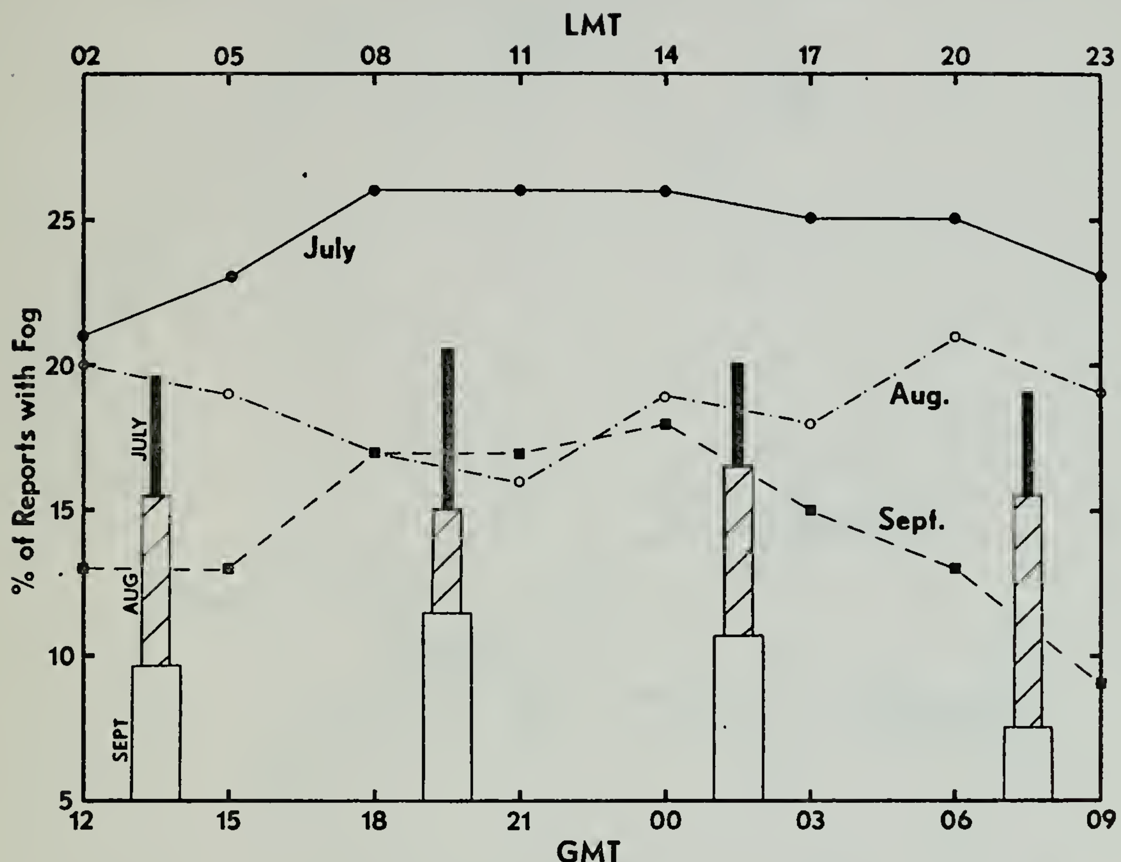

Figure 4. Diurnal distribution of percentage of reports with fog at each of the eight synoptic times for Ocean Station Papa (50N 145W), 1963-68. Line graph values derived from the modified SSR program; bar graph values taken from [5].

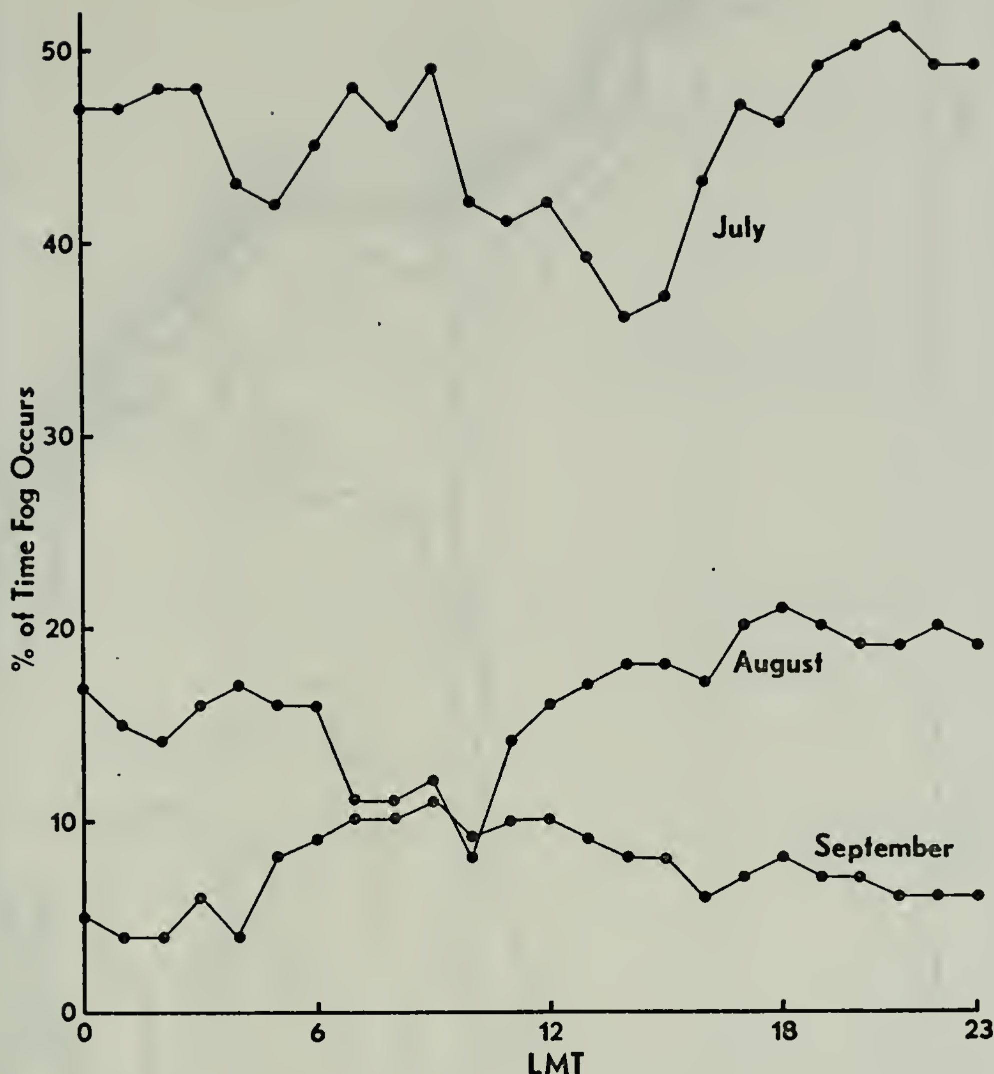

Figure 5. Diurnal distribution of marine fog occurrence at Ocean Station Sierra (48N 162E), determined from observation logs. The ordinate indicates the percentage of days for which fog was observed at each local hour.

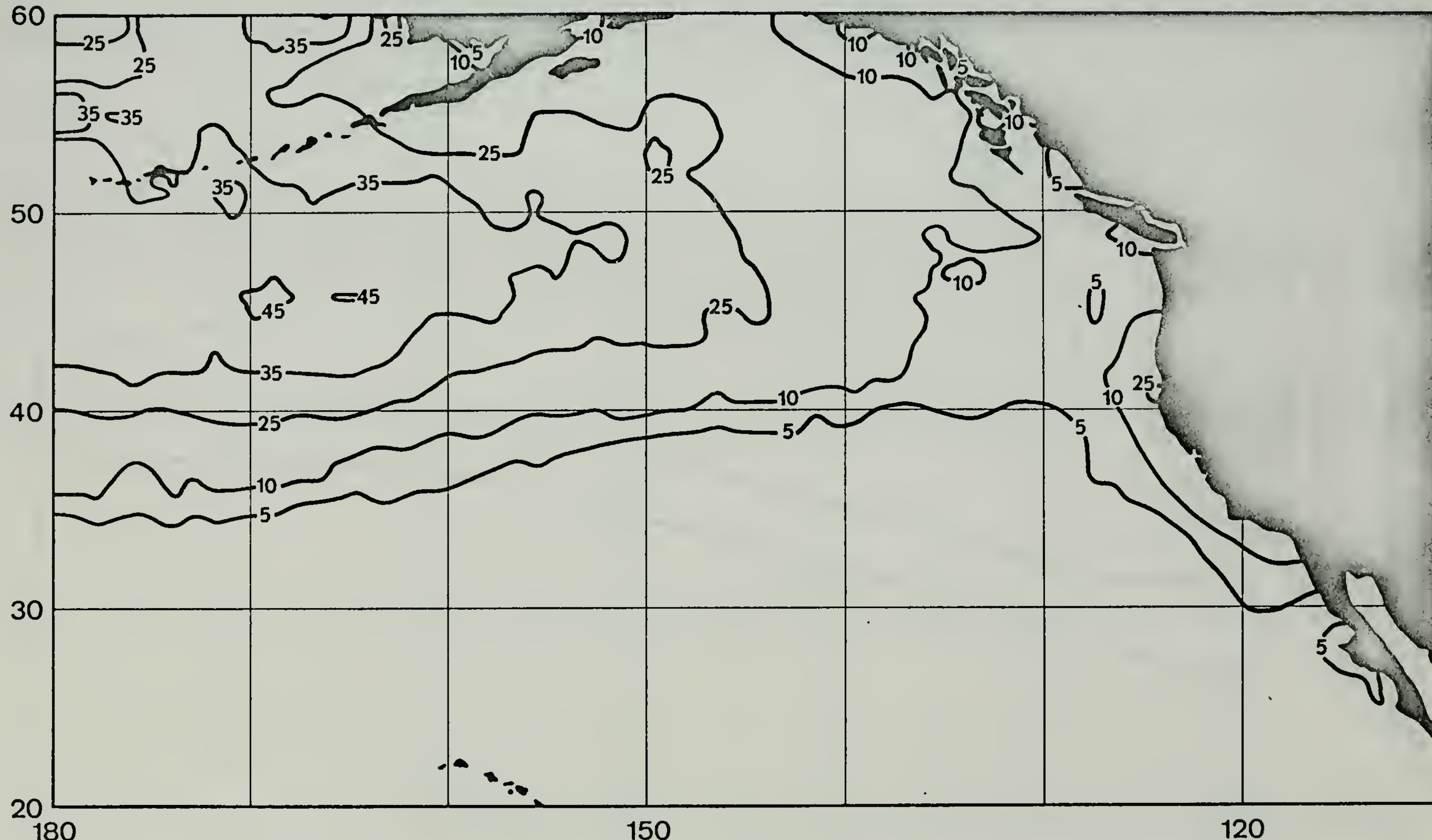

Figure 6. Marine-fog frequencies for July, eastern North Pacific Ocean, derived from the SSR program developed in this study. Isolines in average percentage occurrence of fog from 1963-72 data base.

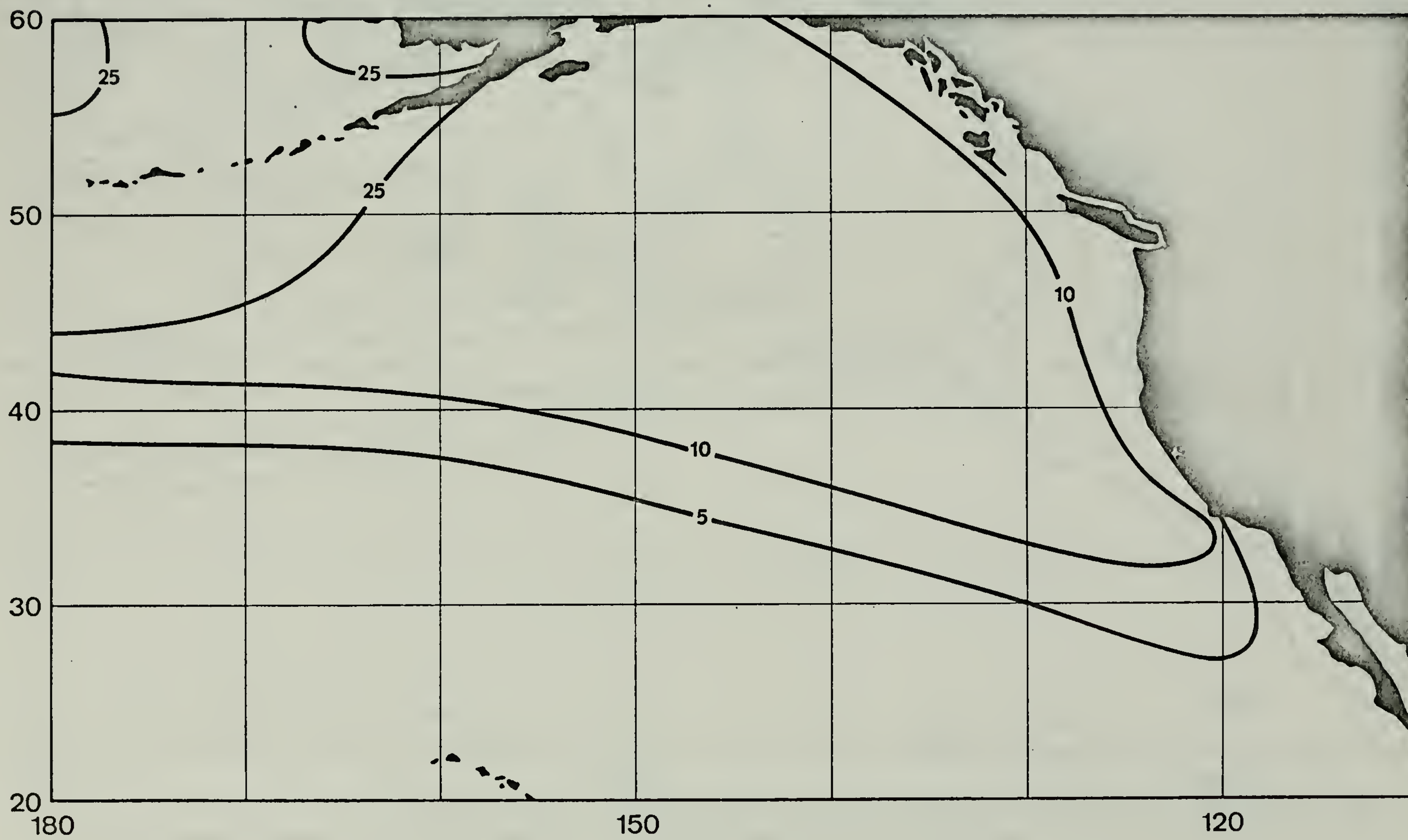

Figure 7. Marine-fog frequencies for July, eastern North Pacific Ocean, from [3]. Isolines in average percentage occurrence of fog.

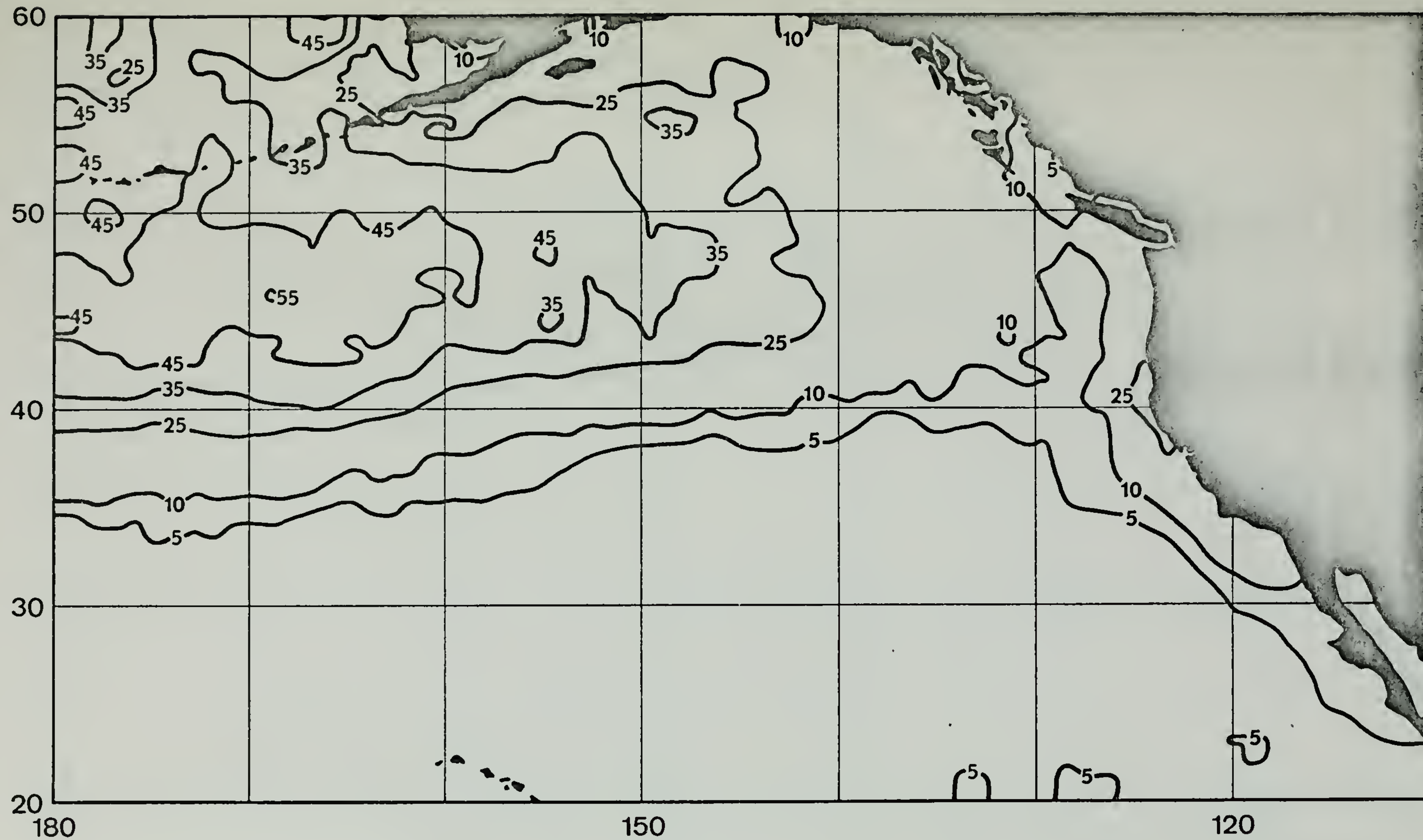

Figure 8. Marine-fog frequencies for July, eastern North Pacific Ocean, resulting from application of the percentage-of-reports-with-fog method. The SSR scheme was used to identify the observations classified as foggers. Isolines in average percentage occurrence of fog.

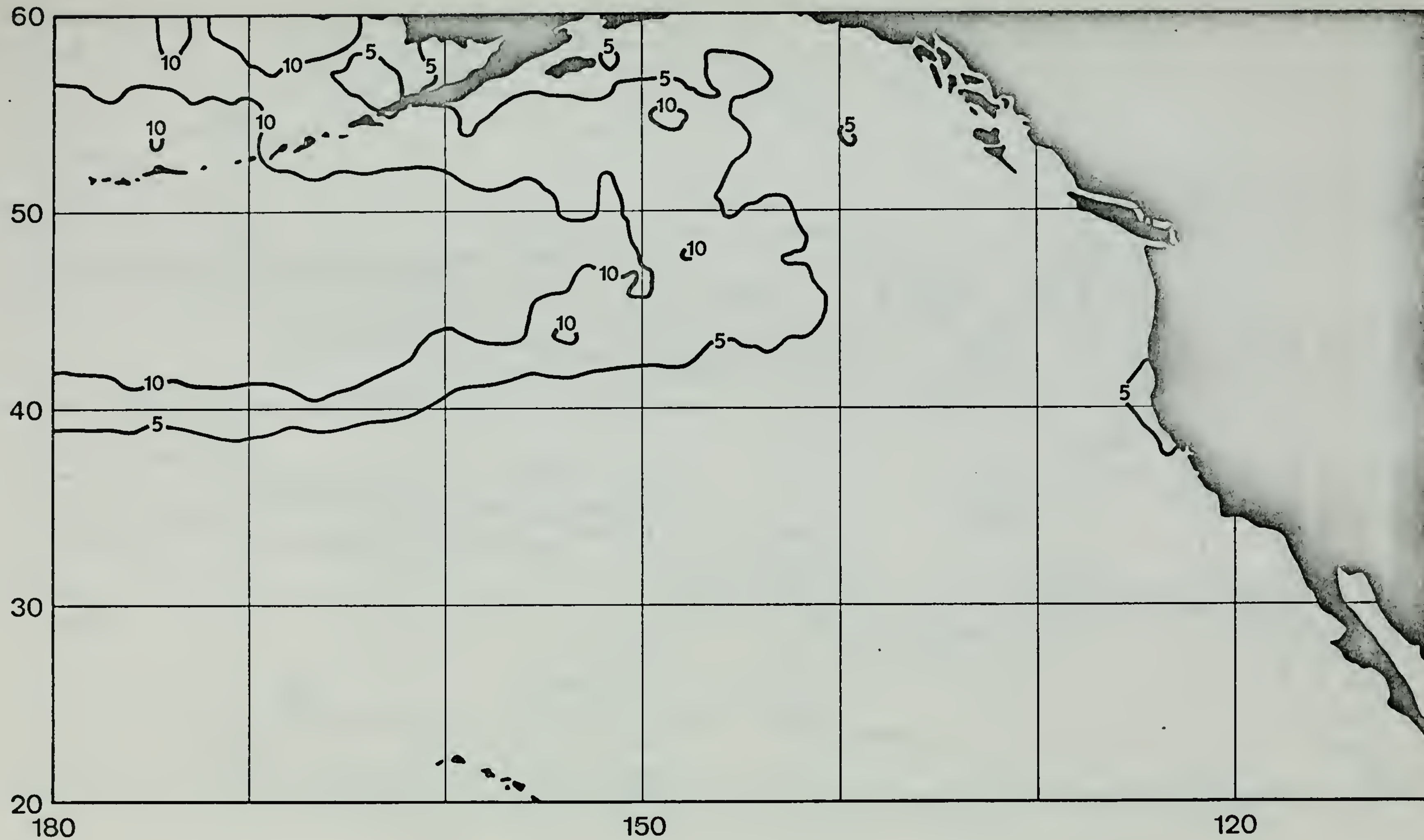

Figure 9. Marine fog frequencies for July, eastern North Pacific Ocean, resulting from application of the days-with-fog method, as interpreted from [3] and Figure 3. The SSR scheme was used to identify observation days classified as foggers. Isolines in average percentage of occurrence of fog.

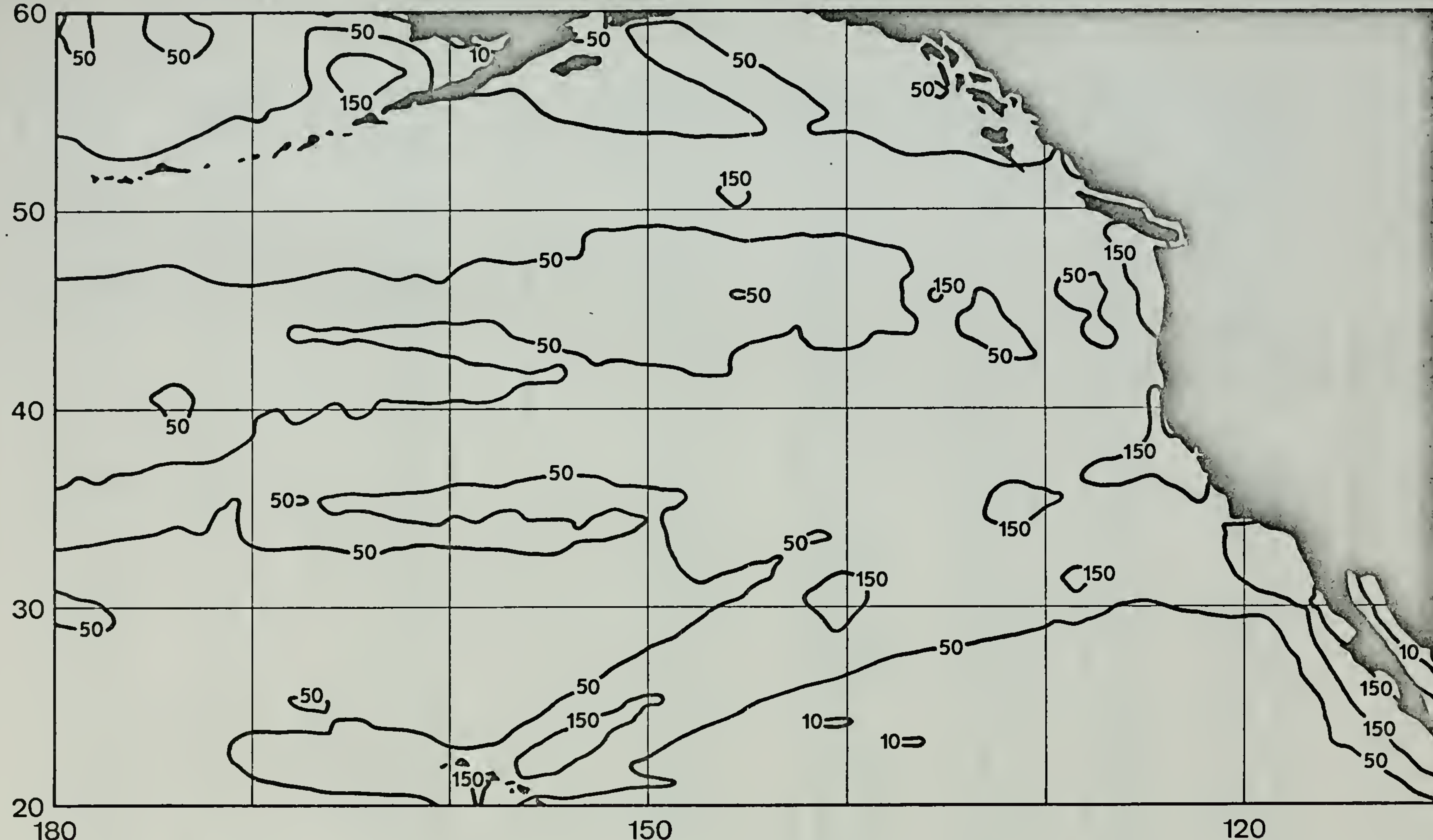

Figure 10. Distribution of eastern North Pacific Ocean marine synoptic reports for the 10-year period, 1963-72. Isoline values: 10, 50 and 150 reports.

LIST OF REFERENCES

1. Wheeler, S. E., 1974: Effects of Fog on Naval Operations, M.S. Thesis, Department of Oceanography, Naval Postgraduate School, Monterey, California (to be published).

2. Barker, E. H., 1973: Oceanic Fog, A Numerical Study. Technical Paper No. 6-73, Environmental Prediction Research Facility, Monterey, California, 65 pp.

3. Guttman, N. B., 1971: Study of Worldwide Occurrence of Fog, Thunderstorms, Supercooled Low Clouds and Freezing Temperatures. National Climatic Center, EDS, NOAA, Asheville, N.C., (NAVAIR 50-1C-60; for Naval Weather Service Command), 70 pp.

4. Crutcher, H. L., and O. G. Davis, 1969: Marine Climatic Atlas of the World, v. VIII, The World. National Weather Records Center, Asheville, N.C. (published as NAVAIR 50-1C-54; for Naval Weather Service Command), 179 pp.

5. Naval Weather Service Environmental Detachment, 1974: Northeast Pacific Environmental Scenario, Federal Building, Asheville, N.C. (work performed by National Climatic Center, Asheville, N.C. for Naval Weather Service Command), 263 pp.

6. Fleet Weather Central, 1972: Climatology of California Coastal Waters. Naval Air Station, Alameda, California, 110 pp.

7. U. S. Naval Weather Service Command, Summary of Synoptic Meteorological Observations (various areas). Prepared by Naval Weather Service Environmental Detachment, Federal Building, Asheville, N.C. (Available in separate volume from Federal Clearing House for Scientific and Technical Information, Springfield, Virginia).

8. Army Air Force, 1944: Fog and Low Ceiling Frequencies Along the U.S. Pacific Coast. Report No. 30, Weather Division, Hdq, Army Air Force (by direction of the Weather Research Center, Statistics Div.,U.S. Weather Bureau),52pp.

9. U. S. Department of Commerce, 1969: Federal Meteorological Handbook No. 2, Synoptic Code. (Also NAVAIR 50-1D-2, U. S. Navy, Department of Defense), Superintendent of Documents, U. S. Government Printing Office, Washington, D. C., 98 pp.

10. Grisham, P. O., 1971: An Investigation of Marine Fog Formation and Occurrence over the North Pacific Ocean Area, Research Paper, Department of Meteorology, Naval Postgraduate School, Monterey, California, 35 pp.

11. Nelson, T. S., 1972: Numerical-Statistical Prediction of Visibility at Sea, M.S. Thesis, Department of Meteorology, Naval Postgraduate School, Monterey, California, 36 pp.

12. Stevenson, R. E., 1963: The Summer Fogs Along the Yorkshire Coast, England. Published in Essays in Marine Geology in Honor of K. O. Emery, T. Clements, Editor, University of Southern California, University Park, Los Angeles, California, pp 145-170.

13. Leipper, D. F., 1948: Fog Development at San Diego, California. Sears Foundation: Journal of Marine Research, v. VII, No. 3, pp 337-346.

14. Misciasci, F., Jr., 1974: An Investigation into the Synoptic Occurrence and Forecast Ability of Marine Fog at Ocean Station Vessels Quebec and Sierra During the Months of May and June 1952, M.S. Thesis, Department of Oceanography, Naval Postgraduate School, Monterey, California (to be published).

15. Naval Weather Service Environmental Detachment, 1973: Northeast Atlantic Environmental Scenario, Federal Building, Asheville, N.C. (work performed by National Climatic Center, Asheville, N.C., for Naval Weather Service Command), 174 pp.

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